Imaging Radar For The Study Of Land Cover And Land Use Change*A Brief Review*

Guoqing Sun
Department of Geography, University of Maryland
gsun@glue.umd.edu

OUTLINES

- **Introduction**
- **Scattering Mechanisms and Radar Image Characteristics**
- **Data Availability**
- **Example of Applications**
- **Potential and Limitations**
- **Future Radar Missions**

INTRODUCTION

- Provide a <u>brief</u> overview of the utility, availability, and limitation of imaging radar data for the study of land cover and land use change
- <u>Not</u> intend to review all important works
- Try to <u>balance</u> between potential and limitation

Scattering Mechanisms

-Surface scattering
-Double-bounce scattering
-Volumetric scattering

Factors that effect radar backscattering include:
Radar parameters:
Incidence angle
Wavelength and polarization
Targets:
Surface roughness
Moisture contents
Scatterer’s geometry

Major backscattering components from a forest canopy:
-Volumetric scattering from tree crowns
-Ground surface scattering
-Trunk-ground double-bounce scattering
-Crown-ground multiple scattering

Penetration capability of multifrequency radar

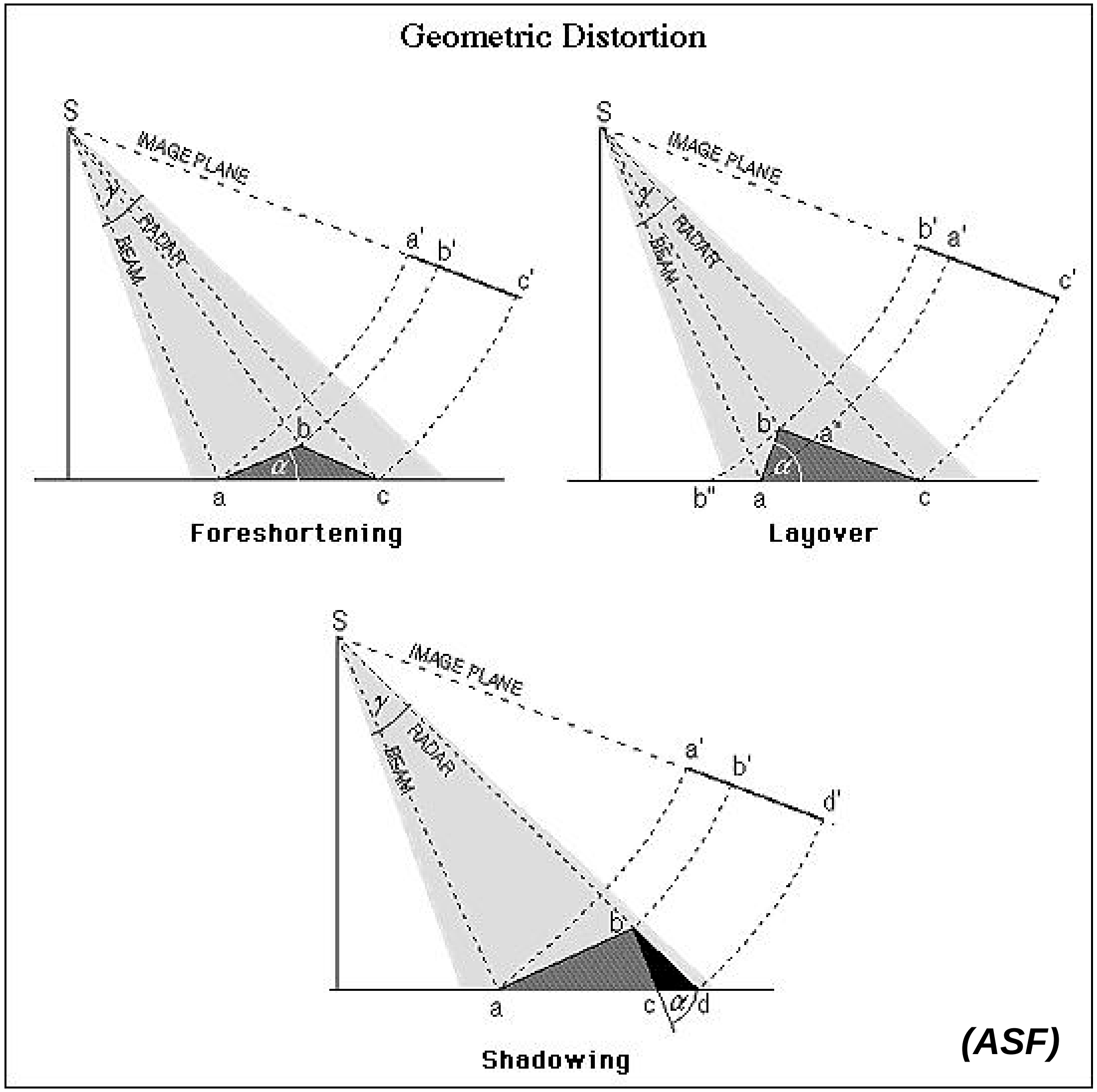
The penetration depth of radar beam depends on

1) radar wavelength Longer wavelength has deeper penetration

2) radar polarization e.g. vertical thin dielectric cylinders have less penetration at V than at H polarization

3) target properties e.g. dense vegetation, wet soil have less penetration

Geometric Distortion of Radar Images

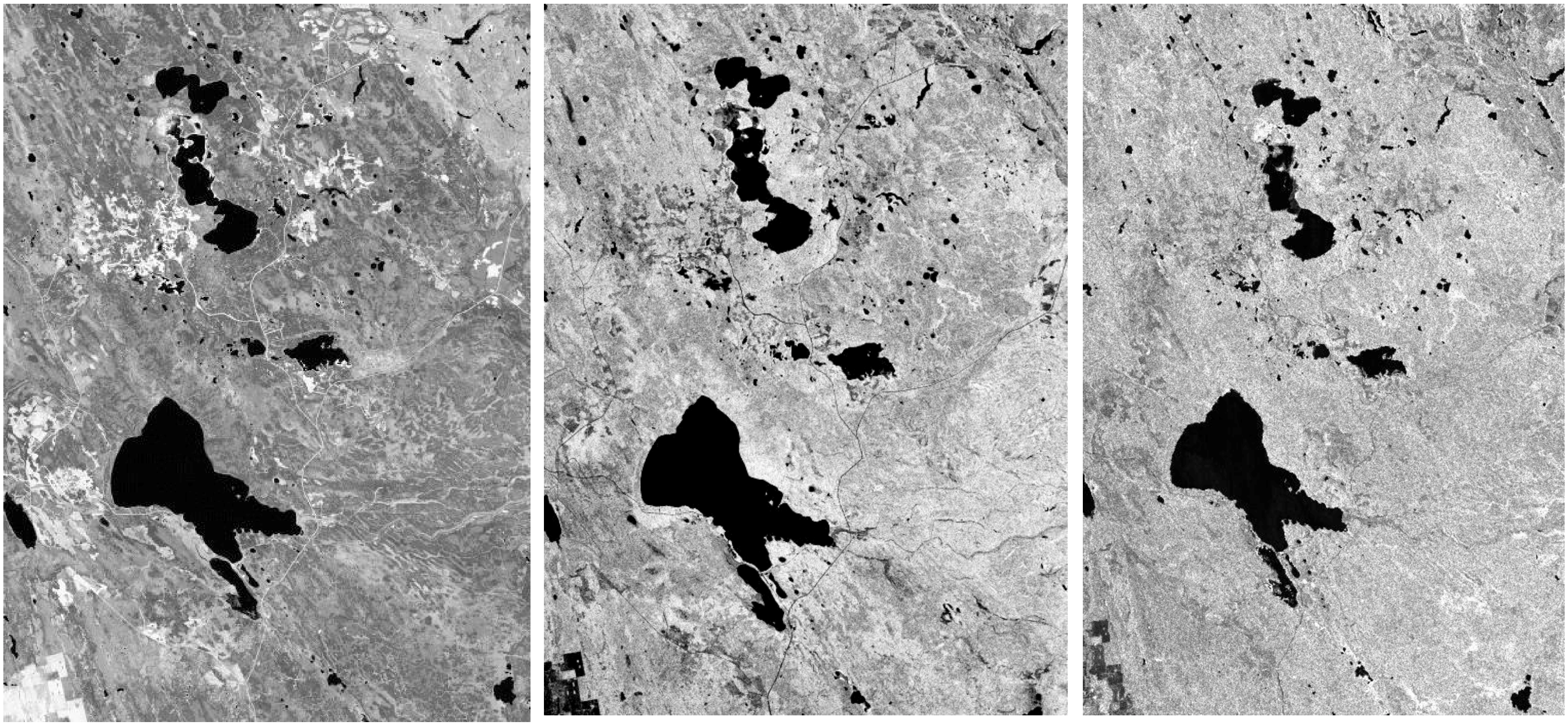


Complementarity Between Optical and Microwave Sensors

TM band 5
September 1994

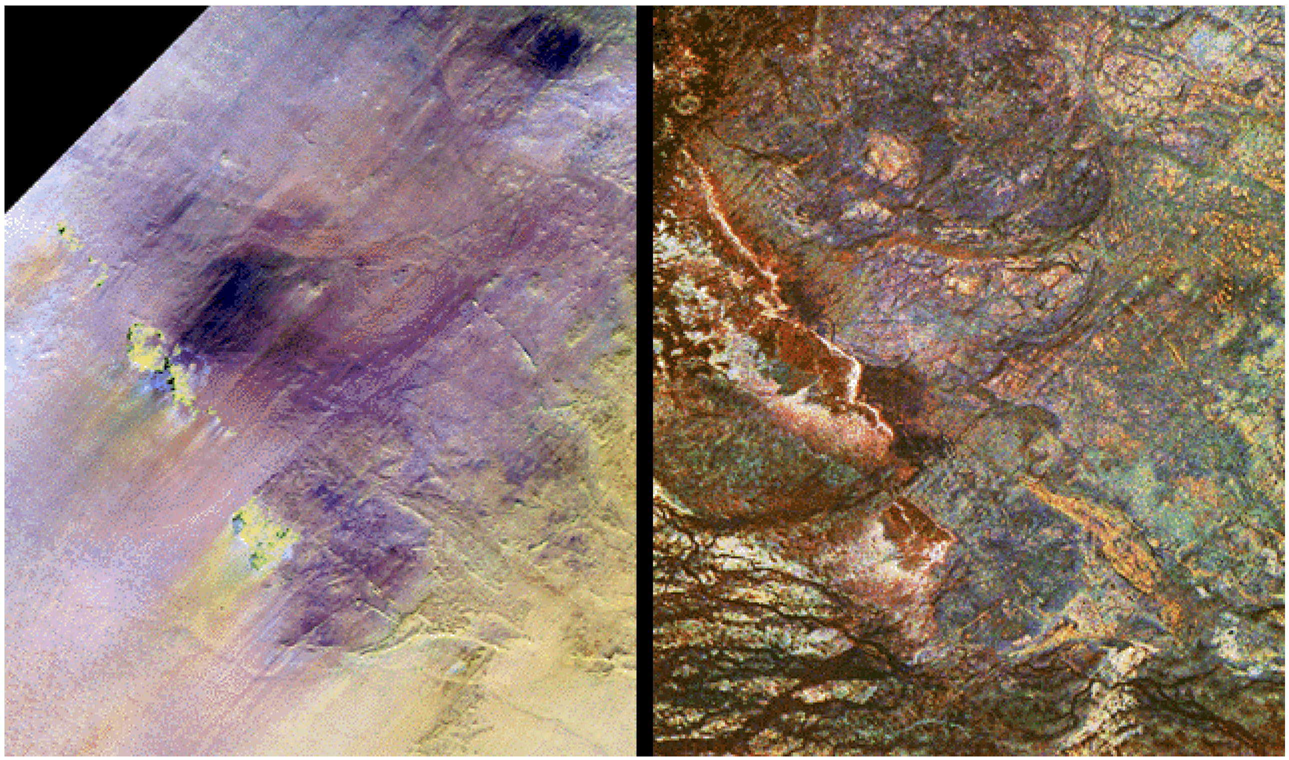
JERS-1 L HH
August 1994

RADARSAT C HH
August 1996



Bright areas on TM5 image are young healthy vegetation (grass, shrub, young aspen, etc).
Bright areas on JERS-1 LHH image are mature forests with high woody biomass, and bright areas on RADARSAT C HH image are rough surfaces, flooded low vegetation along river, at fen sites, etc.

TM bands 7,4,1 false color **SIR-C/XSAR Lhh, Chh, Xvv**



(JPL)

Safsaf Oasis, Egypt

Potential of Imaging Radar

(Temporal, Polarimetric, Interferometric)

- Timely data (all weather, day and night)
- Penetration into canopies, desert, ice
- Sensitive to 3D structure of targets (tree geometry, building type, etc.)
- Direct information about biomass
- Vertical canopy structure from InSAR

Imaging Radar Applications in Land Cover and Land Use Change Studies

Forest characterization
- Forest mapping, biomass estimation, monitoring disturbances

Agriculture
- Crop classification, monitoring and yield estimation

Urban Development
- Land use analysis, Population estimation

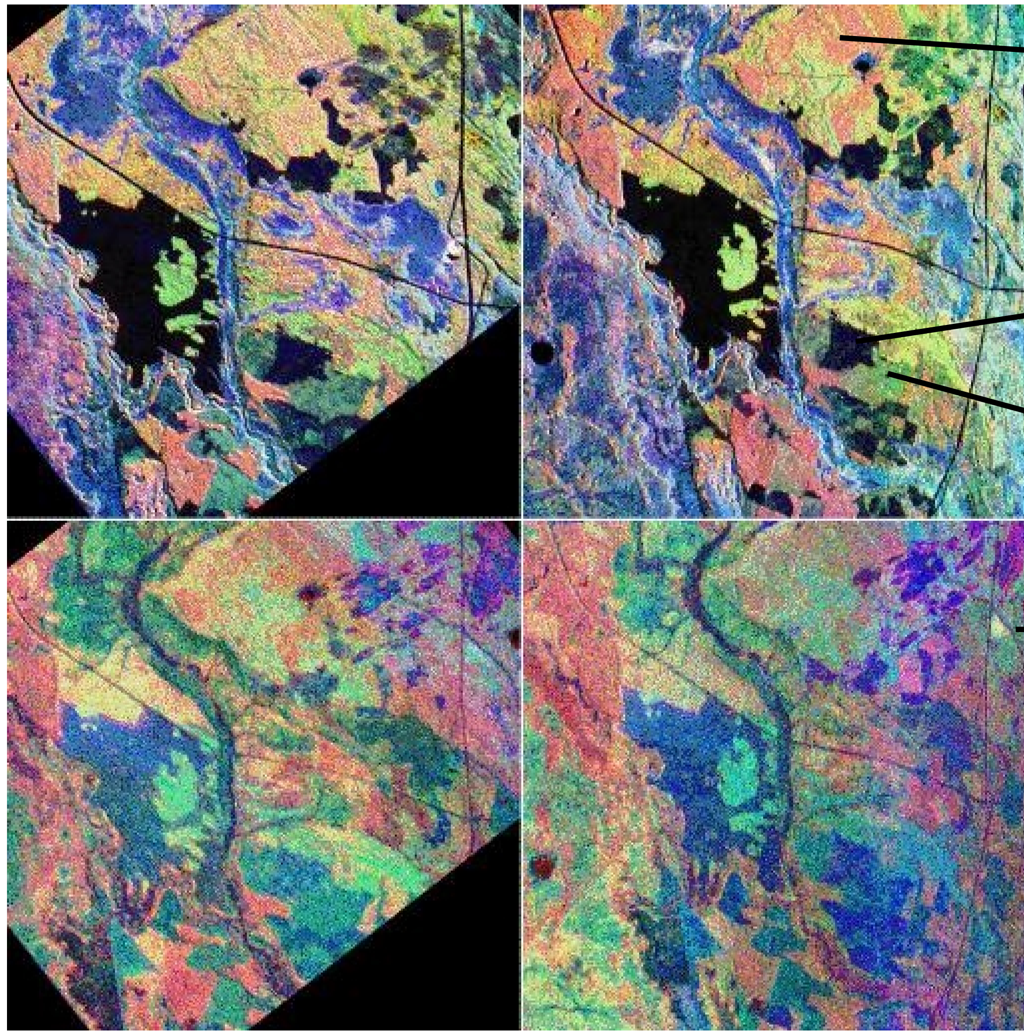
Others

AIRSAR Images (NASA/JPL)

August 12, 1993 | **April 22, 1994**

Total Power P, L, C Bands

HH/VV Ratio P, L, C Bands



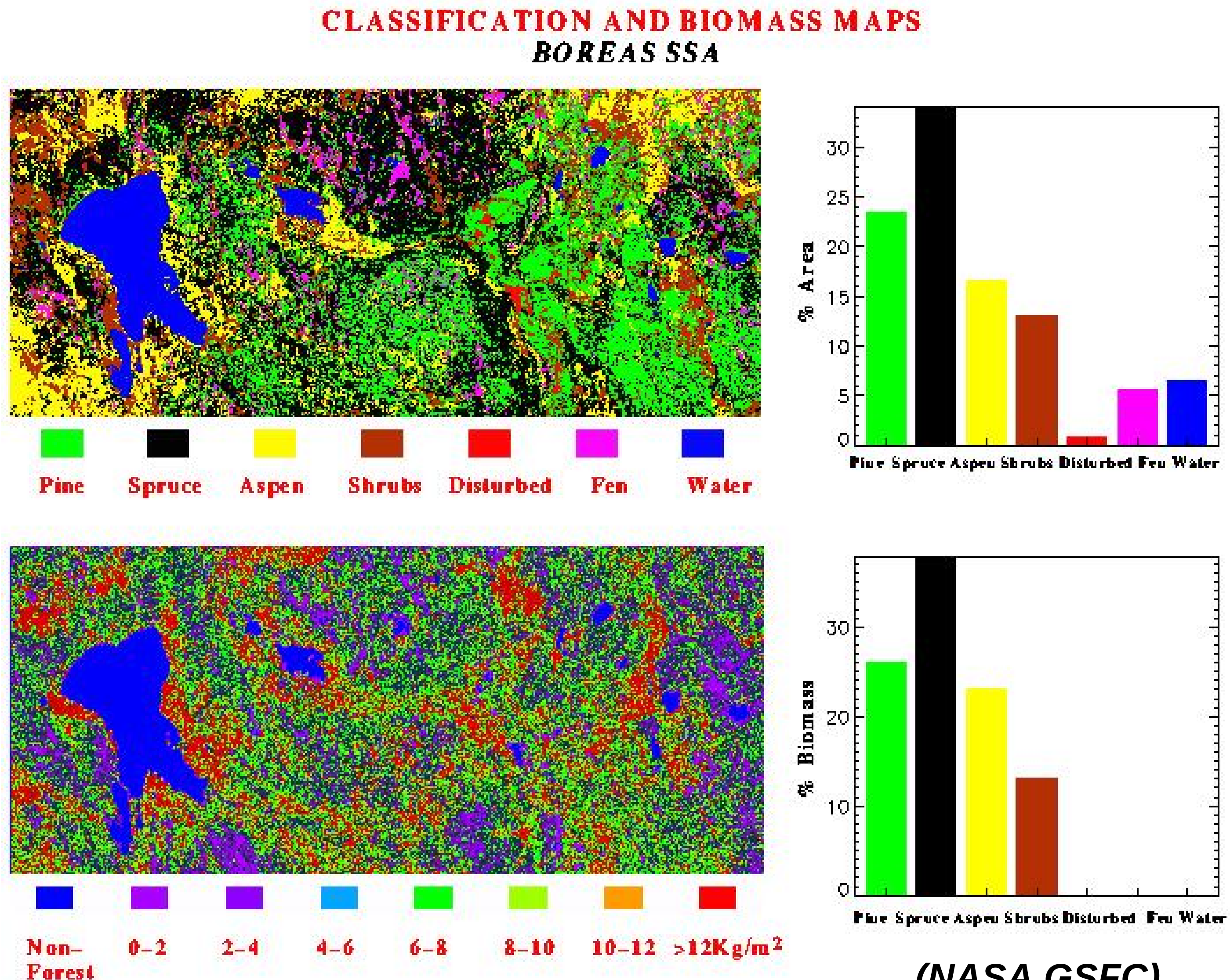
Old Jack Pine Reddish areas are wetter, with alders

Clear cut, very young jack pine

Young Jack Pine ~ 15 years old

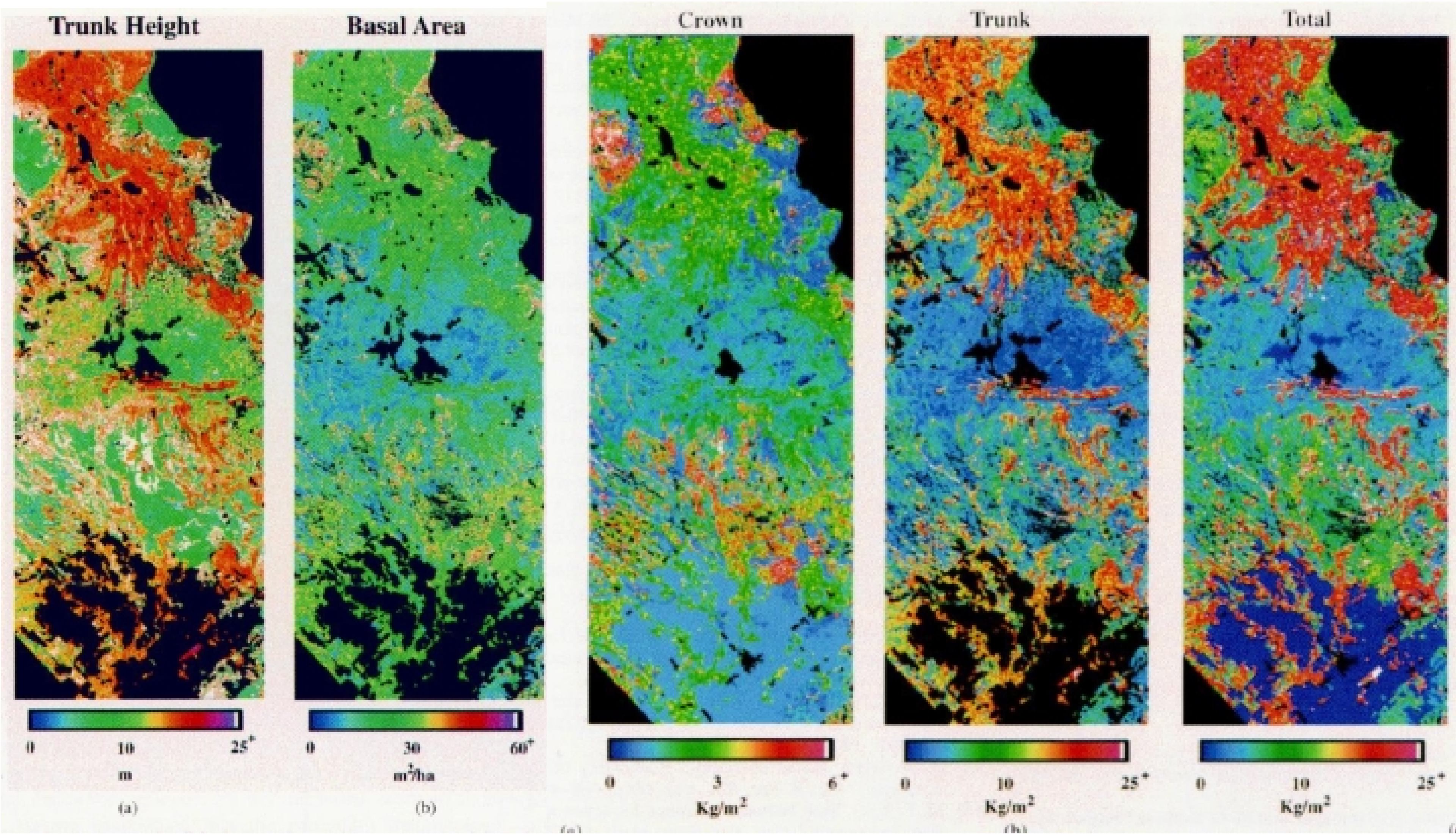
New burns in 1993 trees dead, but only leaves and small branches burned

Forest Classification and Biomass Estimation
From SIR-C Radar Images, in Canada

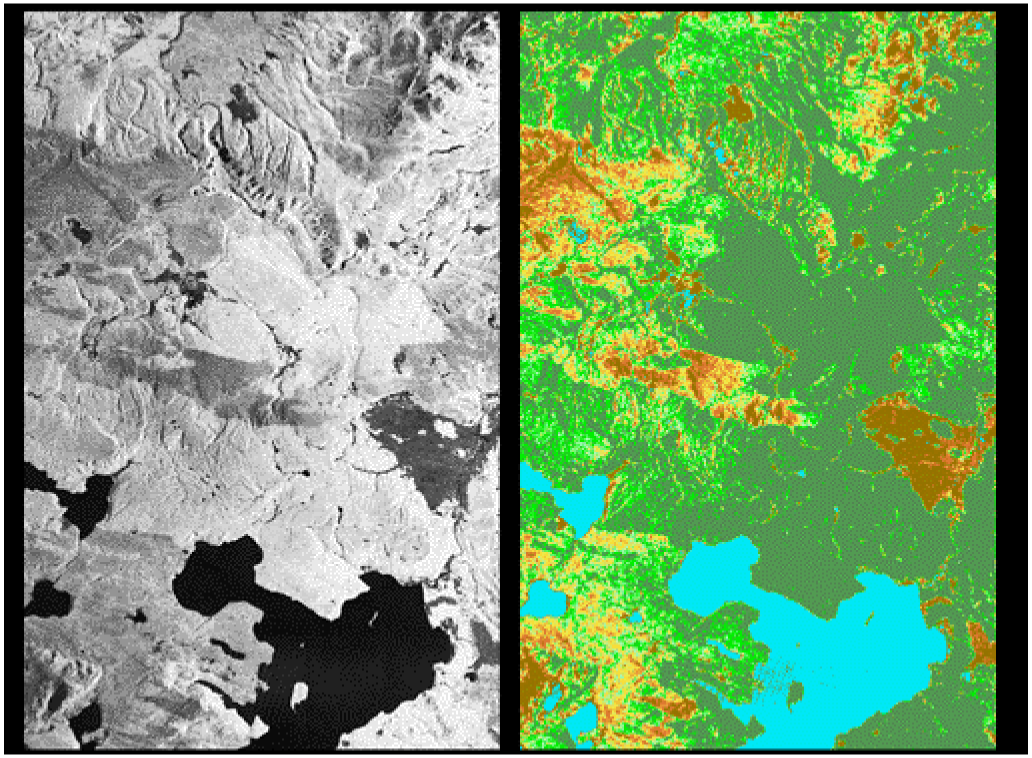


(NASA GSFC)

Trunk Height, Basal Area, Biomass of Crown, Trunk, and Total From SIR-C Data (Dobson et al)



Non-burned Forests and Forests at Different Stages of Fire Succession



Yellowstone National Park, Wyoming, The image at the left is L band HV image obtained on Oct 2, 1994 by SIR-C/XSAR Mission. The image on the right is derived biomass image, showing the non-burned forests and recovery of forests after a fire.
Colors of brown, light brown, yellow, light green , green represent biomass levels of <4, 4-12, 12-20, 20-35, and > 35 tons per hectare.

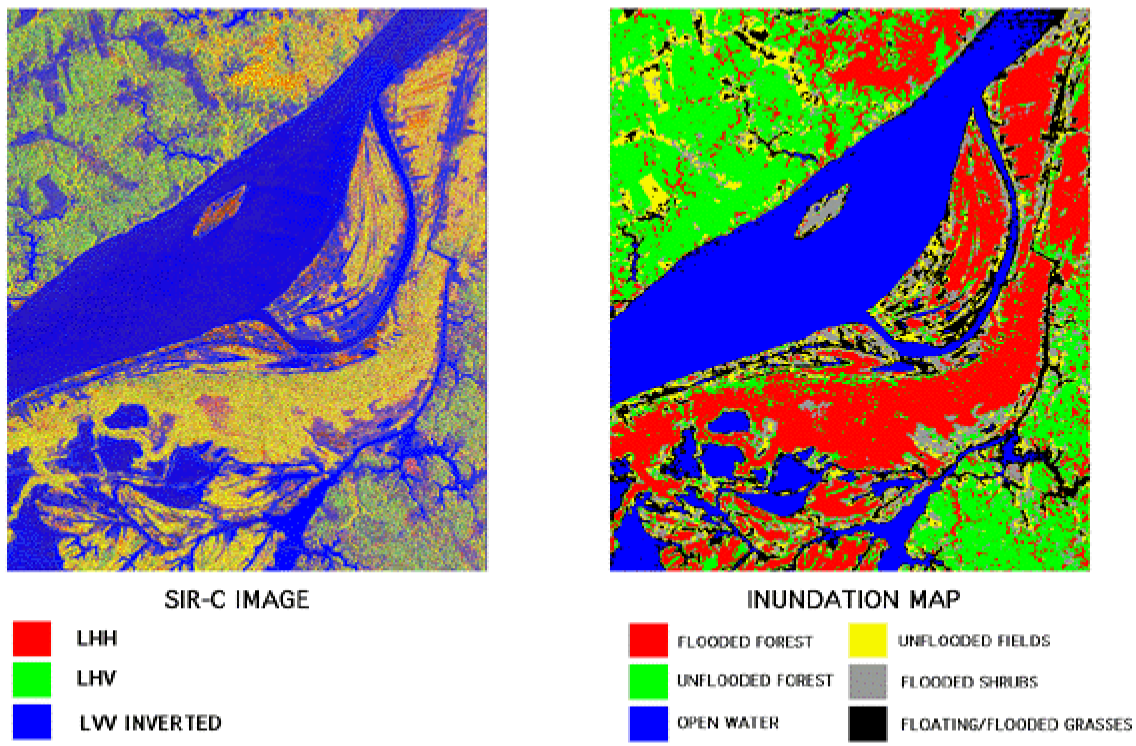
(NASA JPL)

SIR-C/X-SAR

MANAUS, BRAZIL SUPERSITE

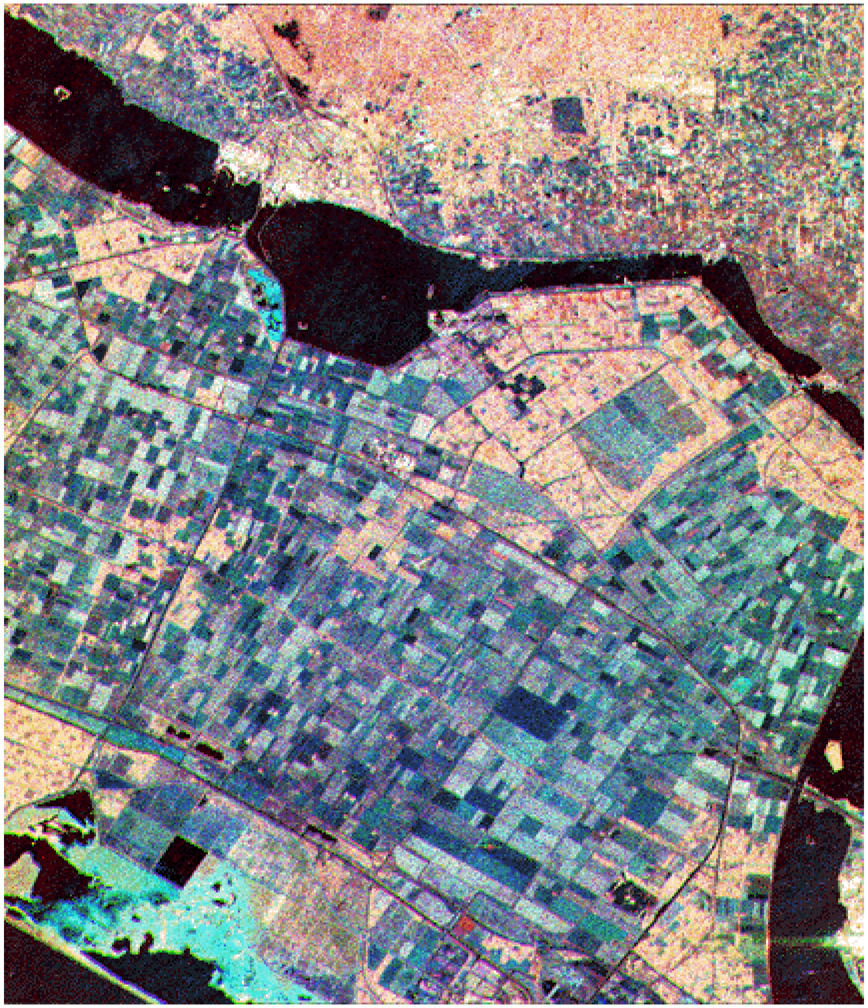
INUNDATION MAP

APRIL 12, 1994



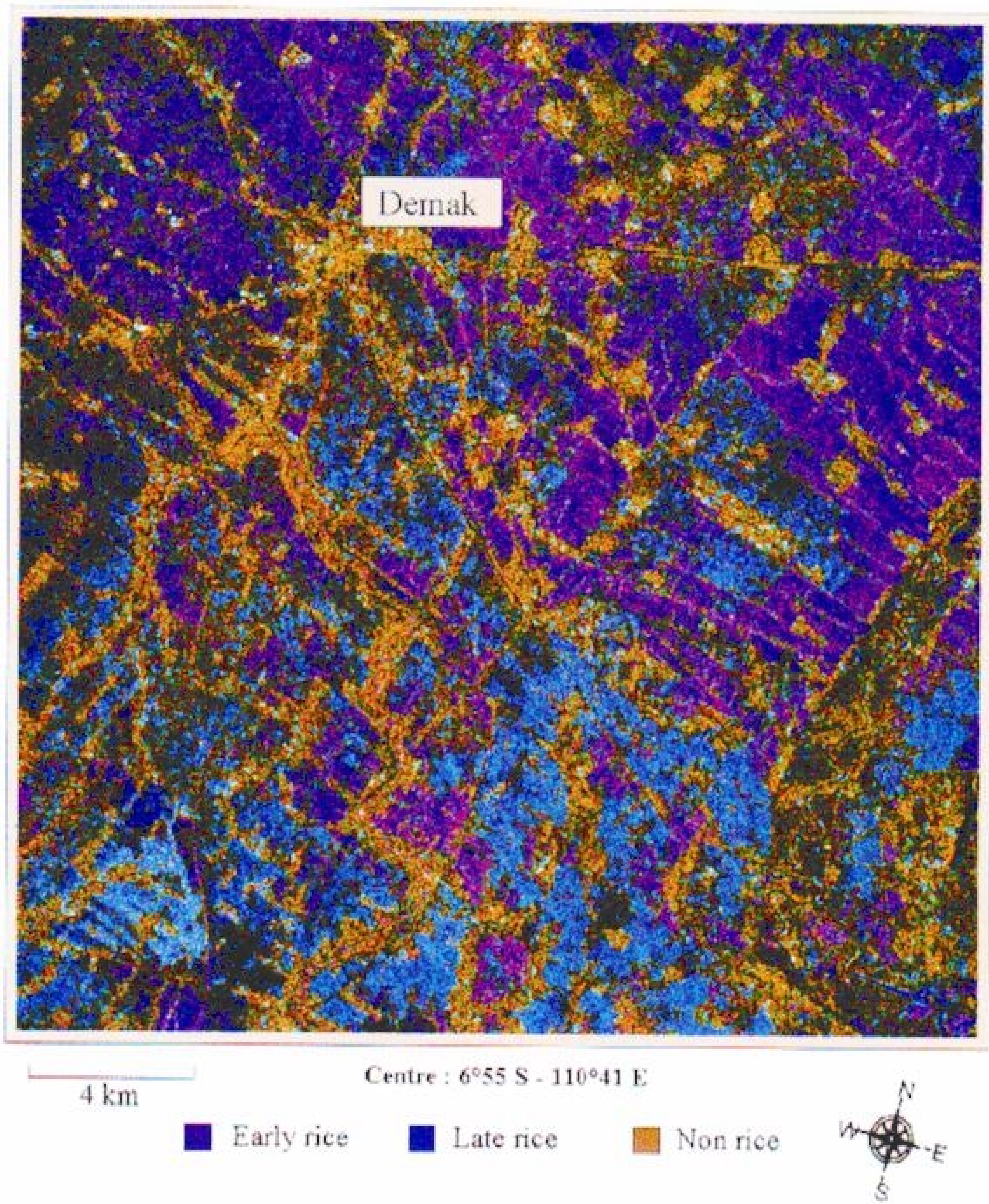
(NASA JPL)

Agriculture, SIR-C/XSAR Image



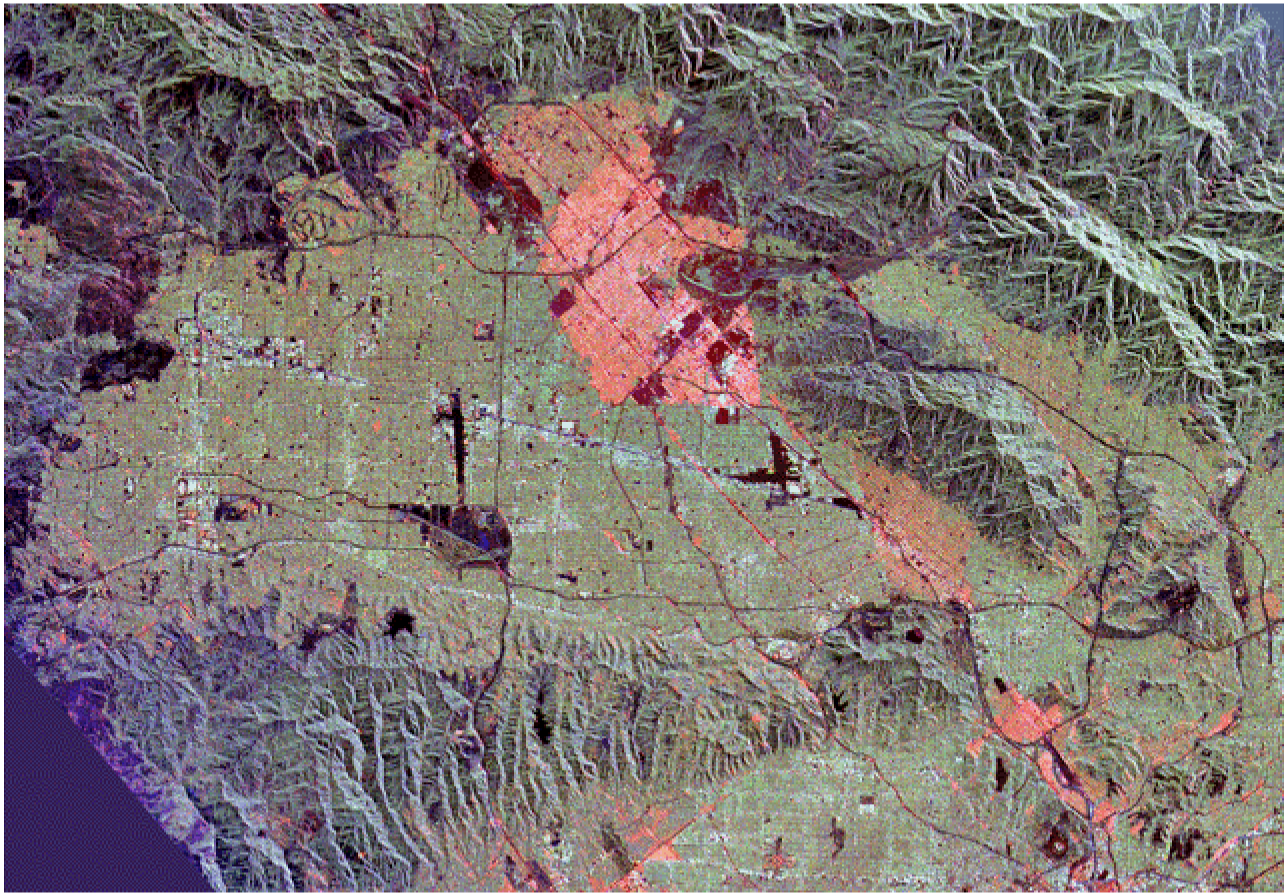
This is a three-frequency, false color, SIR-C/X SAR image (L band total power - red, C band total power - green, and X band vv - blue) of Flevoland, The Netherlands, taken on April 14 1994. At the top of the image, across the canal from Flevoland, is an older forest shown in red. At this time of the year, the agricultural fields are bare soil, and they show up in this image in blue. The changes in the brightness of the blue areas are equal to the changes in roughness.

(NASA JPL)



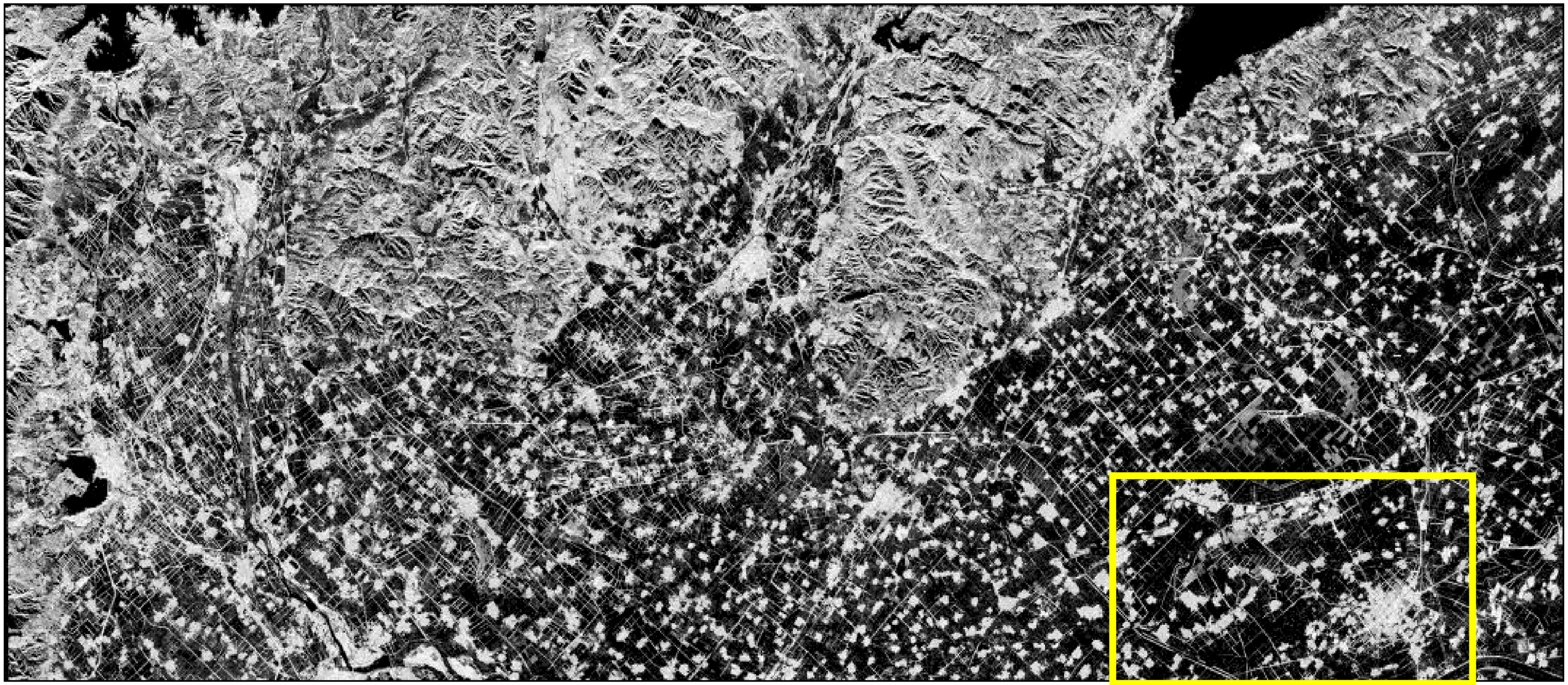
Rice field identification and classification from temporal ERS-1 data

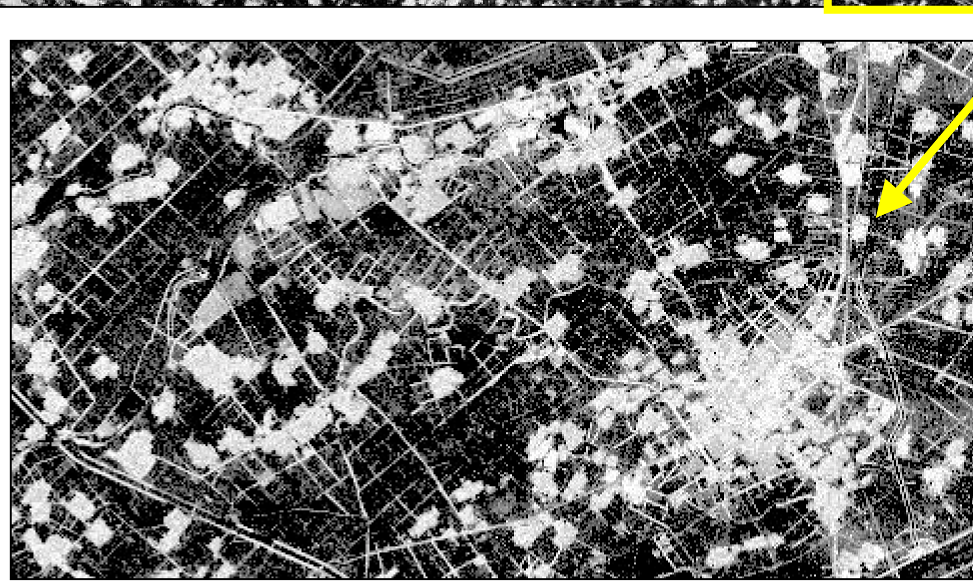
SIR-C Lhh, Lhv, Chv False Color Image



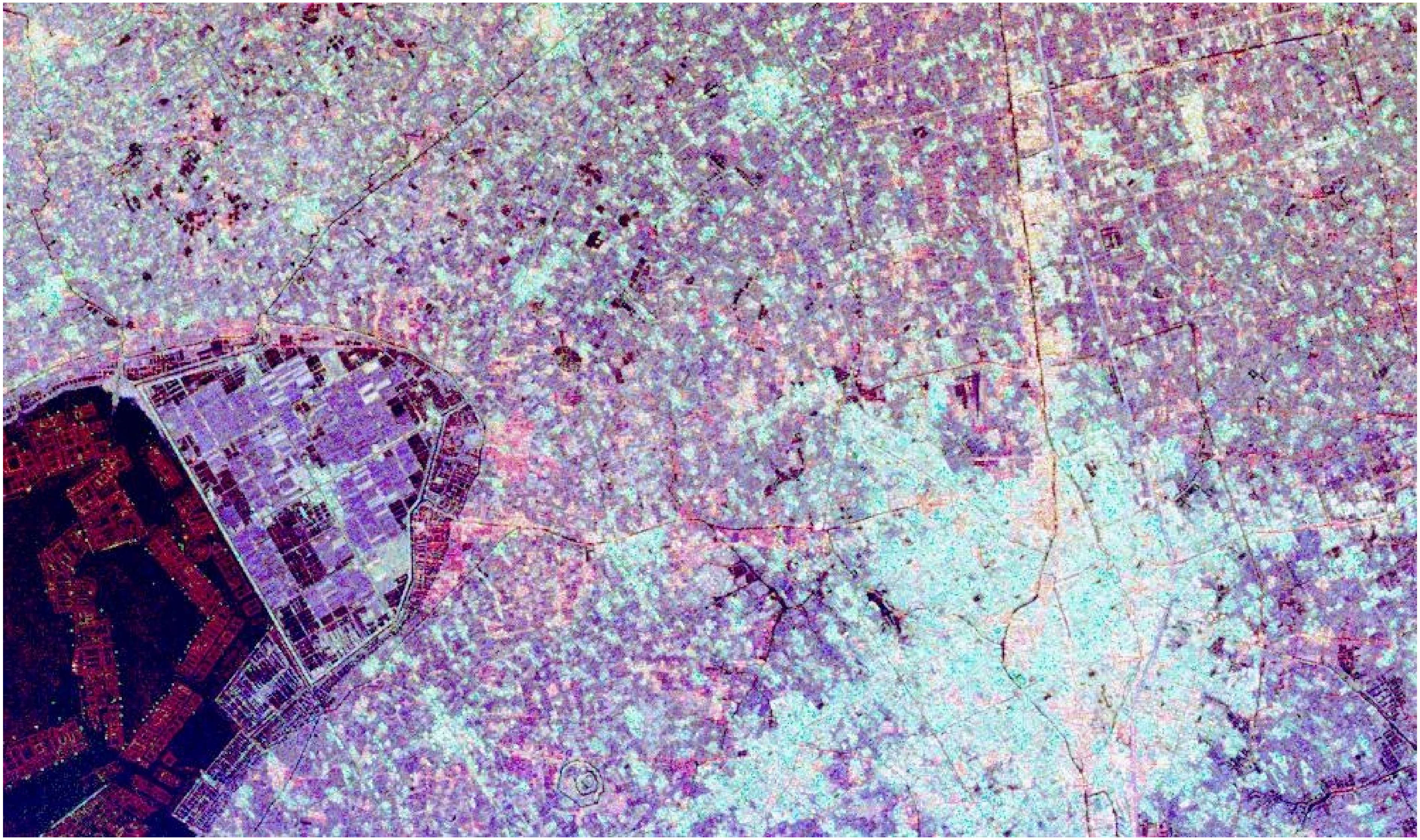
(NASA JPL)

San Fernando Valley, California

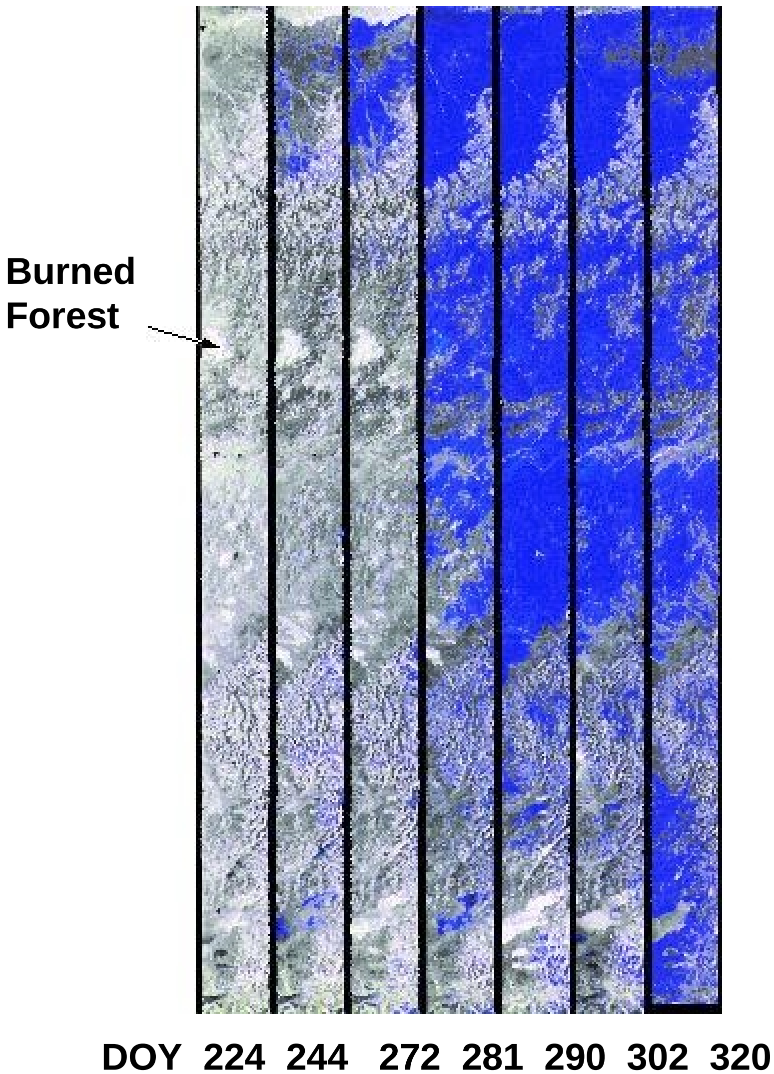




SIR-C Lhh Image
Near Beijing,
China
(40.1N, 117.1E)
April 18, 1994



SIR-C Image of Changzhou (31.6N, 119.6E), China. April 18, 1994. Lhh, Lhv, Chv



Thaw/frozen condition

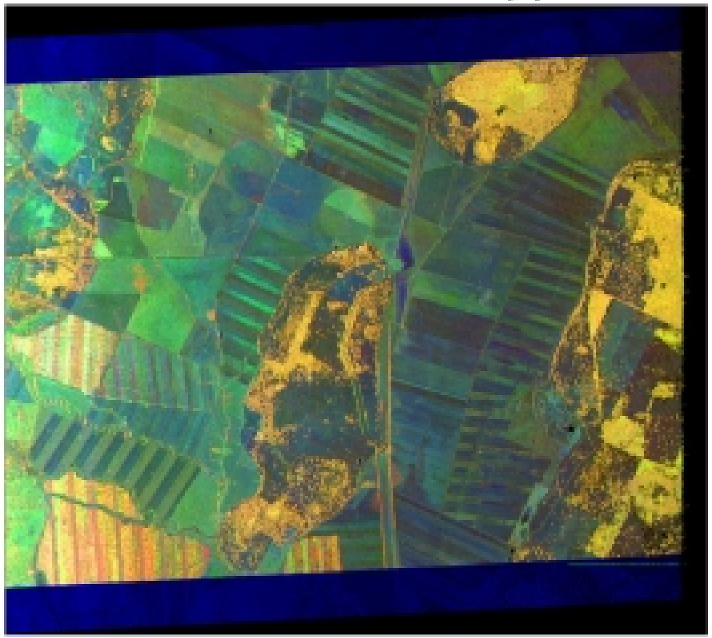
from ERS-1 data
Acquired across Alaska
in 1991
Each transect is
100 km by 1400 km
Areas which show a decrease
in backscatter larger than 3 dB
are coded blue

(Rignot and Way, 1994)

INTEGRATED AIRSAR PROCESSOR

JPL TOPSAR

LIVERPOOL PLAINS 344-1 (C)



P-Band Total Power   L-Band Total Power   C-Band VV

Radar Illumination

Velocity

0 1 kilometers

Pixel Size = 10 m

Date Acquired: 6 Sept 1993

Date Processed: 5 June 1995

CCT ID: TS0049

North

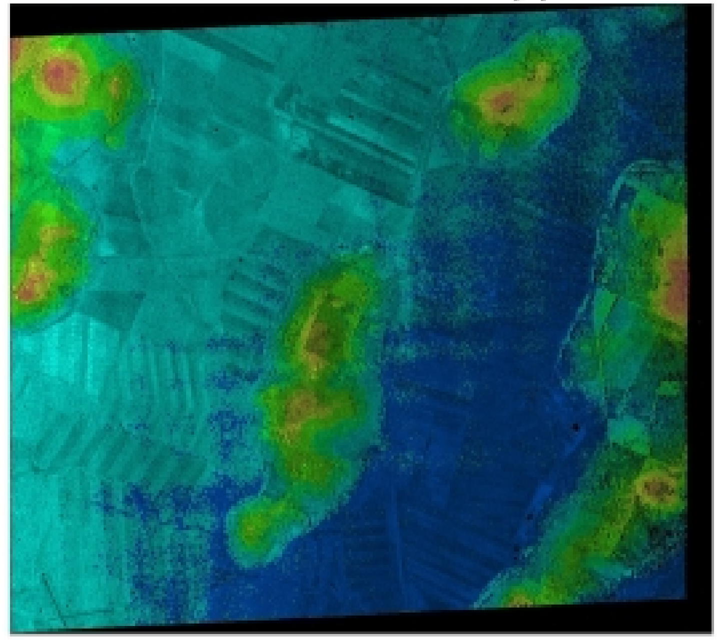
Approximate Image Center:
Latitude: -31.52
Longitude: 150.54

Lines in image: 1062
Samples per line: 1180

INTEGRATED AIRSAR PROCESSOR

JPL TOPSAR

LIVERPOOL PLAINS 344-1 (C)



Elevation (meters)

300 450

Brightness: C-Band VV Radar Cross-Section

Radar Illumination

Velocity

0 1 kilometers

Pixel Size = 10 m

Date Acquired: 6 Sept 1993

Date Processed: 5 June 1995

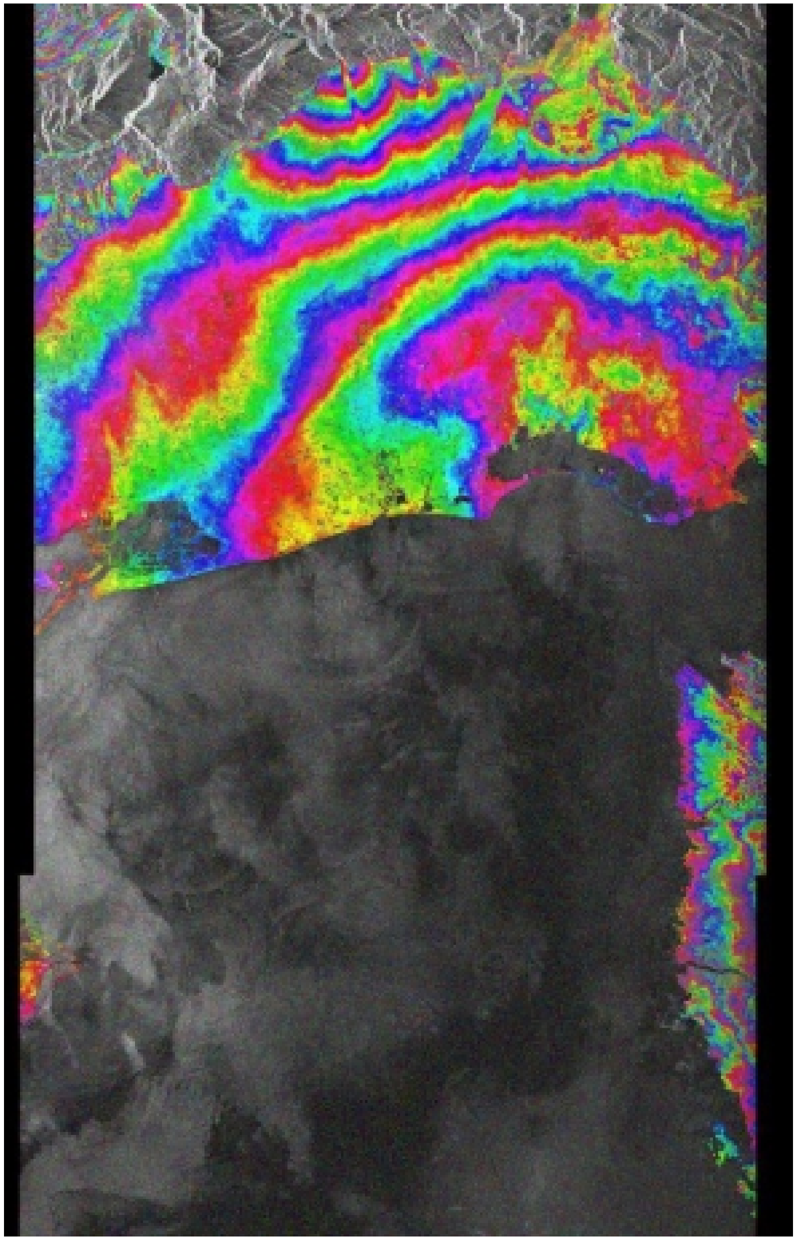
CCT ID: TS0049

North

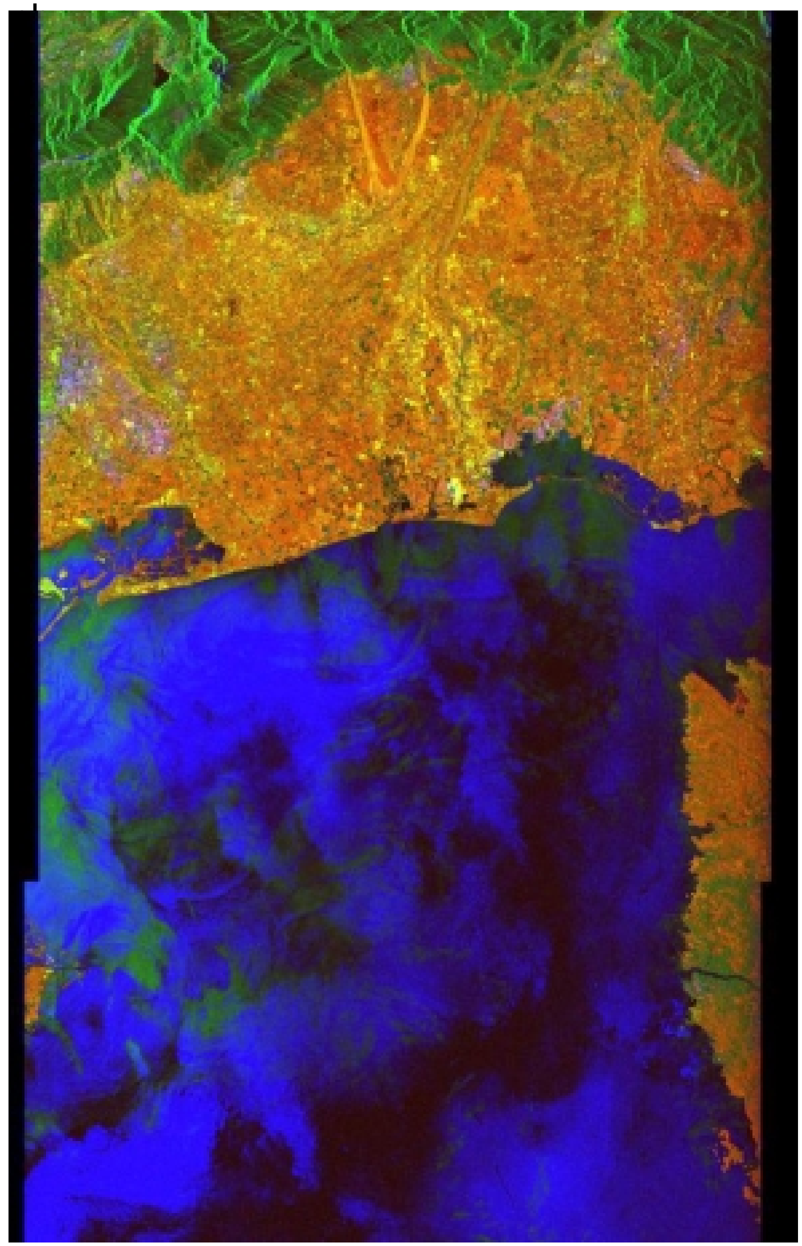
Approximate Image Center:
Latitude: -31.52
Longitude: 150.54

Lines in image: 1062
Samples per line: 1180

Interferometric Phase Image - a cycle of colors represents phase change of 2 PI



Interferometric Land-use Image - Red: Interferometric
coherence, Green: Average intensity, Blue: Intensity



Vince, Italy

Green area - Heavy vegetation
Blue area - Water
Red area - Bare surface
Yellow area - Urban center

(From European Space Agency - ESA)

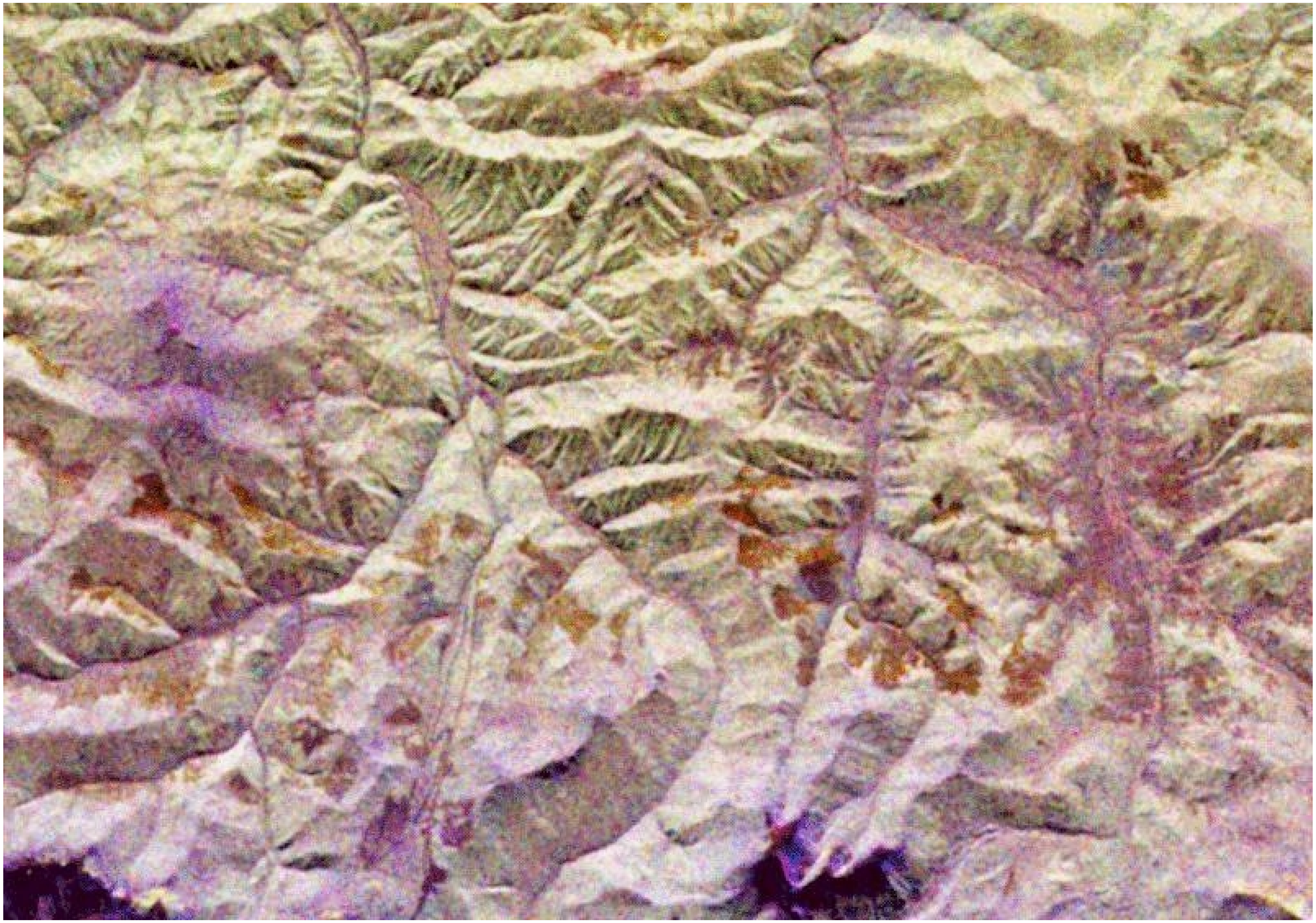
Interferometric Land-Use Image (Virginia Beach, USA)

(From European Space Agency - ESA)

Disadvantages and Limitations of Imaging radar

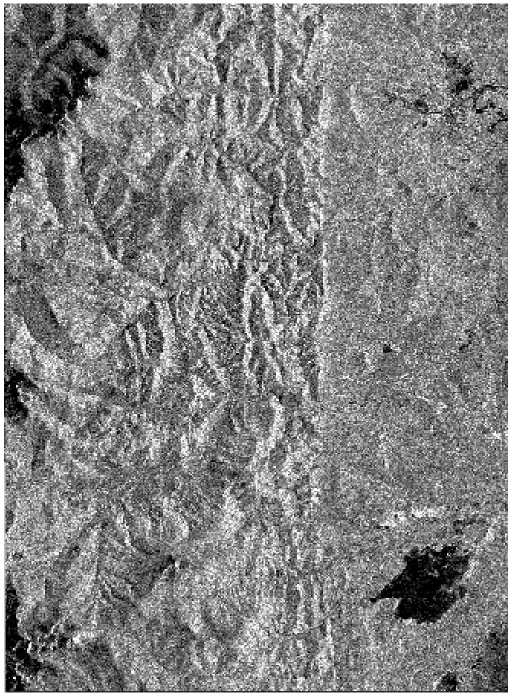
- Speckle degrades image (reduce by multi-look and filtering) and poses difficulties for machine interpretation
- Terrain effect complicates image processing
- Composite signal requires more effort to extract information from it
- Data is not widely available (will be better soon)

Forest clearcut on Mountains of Western Sayani, Russia. SIR-C image, April 16, 1994
Red - L band HH, Green - L band HV, Blue - C band HV, Brown areas are clearings

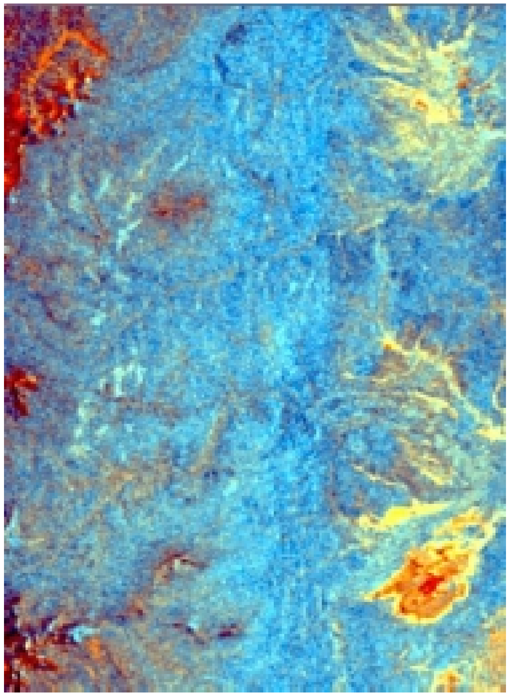


Mapping Forests in Sayani Mountains, Siberia Using SIR-C SAR Data
- Using DEM data for orthorectification and terrain effect correction, or using image ration to reduce terrain effects

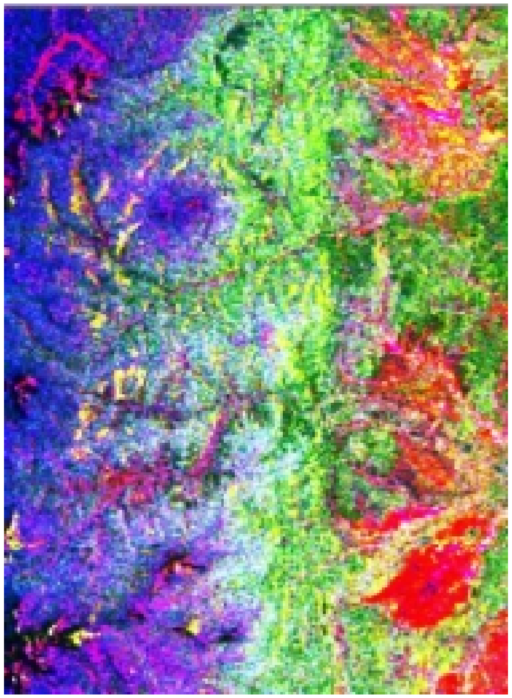
Lhh SIR-C radar image



Ratio Images



PC of ratio images



Existing SAR Data

- <u>SIR-C/XSAR</u> data: April and October, 1994, order from EROS, USGS, (http://edcwww.cr.usgs.gov/landdaac/sir-c/survey.html) $15 per scene (both L and C bands)
- <u>ERS-1/2</u> data: Global cover since 1991, ~$1500 per scene
- <u>JERS-1</u> data: 1992-1998, ~$1500 per scene
- <u>RADARSAT</u> data: $3500 per scene, NASA has a share
- Data received and processed by ASF (Alaska SAR Facility) - $15 per scene

FUTURE SAR MISSIONS

- SRTM (Shuttle Radar Topography Mission) C and X bands InSAR - Sept. 1999, NIMA, NASA, DLR, ASI
- ASAR (Advanced SAR) on ENVISAT-1, C band multi-pol, 2000, ESA
- RADARSAT-2, C band multi-pol, 2001, CCRS, Canada
- ALOS-PALSAR, L band multi-pol, 2002, NASDA, Japan
- LightSAR, L band full-pol, C band hi-res, 2003, NASA

SRTM
(NIMA, NASA, DLR, ASI)

September 16-27, 1999
C and X band InSAR
Coverage: from 60º N to 56º S
Data Products:

1 Terrain height data - Pixel spacing 1” (15-30 m), 5º x 5º
  Absolute accuracy:
    horizontal 20 m
    vertical 16 m
2 Random height error data sets
3 Strip orthorectified image data
    Pixel spacing 15 m

ENVISAT-1 ASAR

(Advanced Synthetic Aperture Radar)

Launch: 2000
Wavelength: C band
Polarization: HH & VV,
HH & HV, VV & VH
Image Products:
Single-look complex - Resolution ~6 m
Image size 100 km x 100 km
Multilook precision - Resolution < 30 m
Image size 100 km x 100 km
Median resolution image: Resolution < 150 m
Image size: Normal 100 km x 100 km,
Wide swath: 400 km x 400 km
Global monitoring: Pixel size 1 km

A Coherent Active Phased Array C band SAR

ASAR's five mutually exclusive modes of operation:
Global monitoring, Wave mode
Image mode (HH or VV)
Alternating polarization mode (Two polarization),
Wide swath mode (HH or VV)

European Space Agency - ESA

RADARSAT-2
(CCRS, CANADA)

Launch: 2001
C band
HH, VV and HV & VH

RADARSAT-2 IMAGING MODES

Beam Modes	Nominal Swath Width	Incidence Angles	Number of Looks	Approx. Resolution
Standard	100km	20-50	1x4	25m x 28m
Wide	150km	20-45	1x4	25m x 28m
Low Incidence	170km	10-20	1x4	40m x 28m
High Incidence	70km	50-60	1x4	20m x 28m
Fine	50km	37-48	1x1	10m x 9m
ScanSAR Wide	500km	20-50	4x2	100m x 100m
ScanSAR Narrow	300km	20-46	2x2	50m x 50m
Standard Quad Polarization	25km	20-41	1x4	25m x 28m
Fine Quad Polarization	25km	30-41	1	11m x 9m
Triple Fine	50km	30-50	3x1	11m x 9m
Ultra-fine Wide	20km	30-40	1	3m x 3m
Ultra-fine Narrow	10km	30-40	1	3m x 3m

ALOS-PALSAR

Phased **A**rray type **L**-band **S**ynthetic
Aperture **R**adar (PALSAR)
NASDA, JAPAN
Launch 2002
on ALOS
(Advanced Land Observing Satellite)

Altitude: 700 km
Inclination: 98º
Recurrent: 45 days

L band, Multiple polarization

Mode	Resolution	Swath
Fine resolution	10-20 m	70 km
ScanSAR	100 m	250 - 360 km

LIGHTSAR

New earth-imaging Radar Satellite
NASA
Launch Date 2003

L band multiple polarization, resolution 25 m
Swath 100 km
C (X) band high resolution (1-3 m) with narrow
swath in the middle of L band swath
Multiple operation modes: Spotlight, High
resolution strip, Dual or Quad polarization,
Repeat pass interferometric, and ScanSAR

SUMMARIES

- Imaging Radar contributes to LCLUC studies by providing timely, unique and complementary data
- Complexity in Radar image processing and interpretation requires more efforts
- Imaging radar has bright past and future - From Seasat (1978) to LightSAR (2003)